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Final Technical Report

June 1, 1985 - October 31, 1989

NASA Grant NAGW-773

"Energetic Neutral Atoms: 'Imaging' the Magnetospheric Ring Current"

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Principal Investigator: Edmond C. Roelof
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1. SUMMARY OF RESEARCH ACTIVITIES UNDER NASA GRANT NAGW-773

Overview

Magnetospheric imaging is a new discipline whose goal is to make pictures of the energetic particle populations trapped in the magnetic field of Earth (or any other planet). This project demonstrated the technical feasibility and scientific validity of magnetospheric imaging using energetic neutral atoms (ENA) with the publication and quantitative analysis of the first ENA images ever obtained from space [Roelof, 1987]. ENAs are produced when singly-charged energetic (~100 keV) trapped ions make an atomic collision with the neutral hydrogen atoms which boil off the top of the Earth's atmosphere. These hydrogen atoms suffuse the entire trapping volume of the magnetosphere. The energetic ion steals the electron from the atmospheric hydrogen, so the energetic ion is transformed into an energetic neutral atom with a velocity of several thousands of kilometers/second. Moreover, the new-born ENA preserves the velocity that the trapped ion had at the time of the collision. Consequently, any population of energetic ions emits ENAs.

Data Analysis

If one has a directional particle detector on a spacecraft that can separate the ENAs from the local trapped ions, one can construct an ENA image of the global energetic ion distribution. This was accomplished using the data from the Medium Energy Particles Instrument (MEPI, D. J. Williams, PI) on the ISEE-1 spacecraft. The primary data were

extracted from the measurements from the Magnetospheric Energetic Particle Instrument (MEPI, D. J. Williams, PI) on the ISEE-1 spacecraft. The usable MEPI data set covered the period November, 1977 through September, 1979, and has been compiled on a set of optical disks at JHU/APL. Special computer software was developed at JHU/APL to generate the energetic neutral atom (ENA) images and compare them quantitatively with theoretical simulations based on model energetic ion distributions. The software was originally written for a VAX/VMS mainframe system and portions have been upgraded to run on workstation windows..

Scientific Analysis

The measured ENA images were compared with computer-generated simulated images (based on theoretical models of the trapped ion distributions). These simulations convolved the theoretically predicted ENA fluxes with the known energy and angular response functions of the MEPI detector. It was shown [Roelof, 1987] that significant physical information could be derived from ENA images by the method of 'forward modeling' in which the parameters of the analytic model for the global distribution of ion pressure were adjusted to minimize the difference between the measured and simulated images. Once the ion pressure distribution was derived from the images, the structure of pressure-driven electrical currents that flow throughout the magnetosphere and close through the ionosphere could be computed using a novel application of Euler potentials [Roelof, 1989]. The nightside current system thus derived was strikingly similar in both magnitude and morphology to the Region 2 system.

Impact on Future Magnetospheric Research

The results of this project [Roelof and Williams, 1988; 1990] have been repeatedly cited in justification of future NASA magnetospheric imaging missions to explore the magnetospheres of the Earth (*Inner Magnetospheric Imager*) and the outer planets (*Cassini*).

Personnel and Management

The scientific research was carried out completely by the PI with the assistance (3mm/yr) of a Senior Programmer who developed the necessary computer graphics.

This project was planned and carried out in coordination with NSF Research Program ATM-8507034.

2. PUBLICATIONS AND PRESENTATIONS UNDER NASA GRANT NAGW-773

Refereed Publications

Roelof, E. C., Energetic neutral atom image of a storm-time ring current, *Geophys. Res. Lett.*, **14**, 652-655, 1987.

Roelof, E. C., Remote sensing of the ring current using energetic neutral atoms, *Adv. Space Res.*, **9**, (12)195-(12)203, 1989.

Roelof, E. C., and D. J. Williams, The terrestrial ring current: From *in situ* measurements to global images using energetic neutral atoms, *Johns Hopkins APL Tech. Dig.*, **9**, (2), 144-163, 1988.

Roelof, E. C., and D. J. Williams, Update on global imaging using energetic neutral atoms, *Johns Hopkins APL Tech. Dig.*, **11**, (1 and 2), 72-76, 1990.

Conference Presentations

Roelof, E. C., Energetic neutral atom images of the main phase ring current, *EOS*, **67**, 344, 1986.

Roelof, E. C., D. G. Mitchell, and D. J. Williams, Imaging the ring current ion population using energetic (100 keV) neutral atoms, *COSPAR XX*, Toulouse (France), **III-3**, 1986.

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Williams, D. J., and E. C. Roelof, Examples of magnetospheric particle population ENA images, *IAGA Paper GA2.6-9*, *IUGG* (Vancouver, B. C.), August, 1987.

Roelof, E. C., and D. J. Williams, Energetic neutral atom image of a storm-time ring current, *IAGA Paper GA2.6-8*, *IUGG* (Vancouver, B. C.), August, 1987.

Roelof, E. C., D. G. Mitchell, and D. J. Williams, Comparison of ISEE-1 energetic neutral atom images of ring currents in three geomagnetic storms, *EOS*, **68**, 1418, 1987.

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Zanetti, L. J., B. H. Mauk, A. T. Y. Lui, T. A. Potemra, and E. C. Roelof, The equatorial ring current as determined from AMPTE/CCE and ISEE-1: Implications on modelling efforts, *EOS*, **69**, 428, 1988.

Roelof, E. C., Global topology of electrical currents deduced from ENA images of storm-time ring current ions, *EOS*, **69**, 428, 1988.

Roelof, E. C., Evidence from ENA images for the coupling of the storm-time ring current to Region 2 field-aligned currents, *International Conference on Auroral Physics*, (Cambridge, England), July, 1988.

Roelof, E. C., Remote sensing of the ring current using energetic neutral atoms, *COSPAR XXVII*, (Helsinki, Finland), July, 1988.

Roelof, E. C., Energetic neutral atoms from ISEE-1, *IAGA 5th Assembly, IUGG*, (Exeter, England), August, 1989.